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CONTINUOUS MANUFACTURE OF FLAT PANEL LIGHT EMITTING DEVICES

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CONTINUOUS MANUFACTURE OF FLAT PANEL LIGHT EMITTING DEVICES

FIELD OF THE INVENTION

The present invention relates to the manufacture of flat panel light emitting devices such as displays and extended light sources, an example being organic light emitting diode displays, backlights and area illumination sources and, more particularly, to the patterned deposition of materials such as organic light emitting materials on a substrate.

BACKGROUND OF THE INVENTION

Organic light emitting diode (OLED) light sources and displays are known. Such light sources and displays are constructed by depositing and treating multiple layers of materials such as organic materials on a substrate. When a current is passed through the multiple layers of organic materials, light is emitted. The color of light is dependent on the type of materials. As used herein the term flat panel light source refers to displays, backlights, and area illumination devices.

The deposition of the layers of organic materials in an OLED device is difficult. The materials are sensitive to moisture and must be carefully patterned at a high resolution to enable a pixilated display capable of, for example, displaying images. Small molecule OLED materials are typically deposited by evaporation from a source onto a substrate. It is known to register a mask having extended linear structures with variable widths with a substrate and to translate a source of material past the substrate to form a patterned deposition. This process is described in detail in "Linear Source Deposition of Organic Layers for Full Color OLED" by VanSlyke et al. SID 02 Digest, Vol. 33, No. 2, pp 886-889, 2002. However, this technique is not convenient for continuous manufacture.

US Patent Application No. 2002/0179013A1, published December 5, 2002 by Kido et al. discloses a vapor deposition system that includes a plurality of vapor deposition chambers through which discrete substrates and masks are passed to receive successive deposits of vapor deposition material. A problem

with this approach is the complication of holding and transporting individual discrete substrates.

US 6,328,806 issued December 11, 2001 to Eller discloses a device for treating a band-shaped substrate with a gas. A continuous band-shaped substrate is passed by a deposition station that includes a source of gaseous material and a continuous band-shaped mask. A problem with this approach is the difficulty in making, handling, and cleaning a continuous mask through which multiple depositions are to be made, and the difficulty in maintaining alignment with a continuous substrate and continuous mask for multiple depositions. In addition, continuous masks are expensive to manufacture.

There is a need therefore for an improved continuous method for the application of patterned materials for making flat panel light sources.

SUMMARY OF THE INVENTION

The need is met according to the present invention by providing a method of applying patterned materials for manufacture of a flat panel light source that includes providing a flexible continuous substrate; providing one or more application stations, each application station having, one or more stationary sources of material, a supply of discrete patterned masks for defining a pattern of material to be applied to the substrate, means for attaching the discrete patterned masks to the substrate; means for transporting the substrate and the patterned mask in registration past the one or more stationary sources of material, and means for delivering the masks one at a time to the transporting means; and transporting the substrate and the masks past the one or more application stations.

ADVANTAGES

The present invention has the advantage that it provides a means for the continuous application of materials onto a substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram of a method of depositing materials on a substrate according to the present invention;

Fig. 2 is a schematic diagram showing a method of attaching a mask to a substrate using clamps;

Fig. 3 is a perspective view of a clamp for attaching a mask to the substrate;

Fig. 4 is a schematic diagram of an alternative method of attaching a mask to a substrate using a magnet;

Fig. 5 is a schematic diagram of an alternative method of attaching a mask to a substrate using a magnet;

Fig. 6 is a schematic diagram of an alternative method of attaching a mask to a substrate using a magnet;

Fig. 7 is a schematic diagram of an alternative method of depositing materials on a substrate according to the present invention;

Fig. 8 is a schematic diagram of an alternative method of depositing materials on a substrate according to the present invention;

Fig. 9 is a schematic diagram of an alternative method of depositing materials on a substrate according to the present invention; and

Fig. 10 is a schematic diagram of apparatus for attaching the masks to the substrate.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figs. 1 and 2, a method of applying patterned materials for manufacture of a flat panel display, includes providing a continuous flexible display substrate **10**, supplied for example on a roll **80**; providing one or more application stations **8**, the application stations **8** having one or more stationary sources **14** of material, a supply of patterned masks **12** for defining a pattern of material to be applied to the display substrate **10**, means such as clamps **22** for attaching the discrete patterned masks to the substrate and means (such as powered rollers **82, 84)** for transporting the display substrate **10** and the patterned

masks **12** in registration past the one or more stationary sources **14** of material, and means **43** for delivering the masks one at a time to the transporting means and transporting the display substrate **10** past the one or more application stations **8**. The direction of movement of the substrate **10** and mask **12** are shown by arrows **A** and **B** in Fig. 1 and in subsequent Figures.

As shown in Fig. 10, container **42** holding a stack of masks **12** includes an elevator **46** for moving the masks, one at a time into engagement with substrate **10**. The masks **12** are provided with electromechanical clamps **22** on two opposing edges. As the mask is urged into contact with the substrate **10**, the electromechanical clamps **22** are actuated to grip the edges of the substrate **10**.

The masks **12** are formed as discrete sheets that are supplied in a stacking container **42** and affixed to the substrate **10** as the masks are supplied from the container **42**. After a mask **12** is transported with the substrate **10** past the source of materials, the mask is detached from the substrate **10** and received in a receiving container **42'**. The masks **12** may be either flexible or rigid.

Referring to Fig. 3, the clamp **22** for removably attaching the mask to the substrate includes a body portion **23** and rotatable clips **27** mounted on two opposing edges of the body portion **23**. The clamp **22** may function to hold a flexible mask in a plane, and may also assist in holding the substrate in a plane parallel to that of the mask. The rollers **82** and **84** for transporting the substrate **10** contact only the edges of the substrate and the clips **27**.

Referring to Figs. 4 and 5, alternatively, a magnet **24** may be employed to pull a mask **12** made of a magnetic material into contact with the substrate **10** and hold the mask in registration as it is transported with the substrate **10** past the application stations **8**. As shown in Fig. 5, a series of electromagnets **24** may be transported along with the substrate **10** by a transport mechanism **29**. The electromagnets **24** may be activated at the mask container **42** to pick up and attach a mask to the substrate. After the materials are applied, the electromagnet may be deactivated to release the masks **12** into receiving container **42'**. The contact surface of electromagnets **24** may provide a reference surface for holding

the substrate in a planar configuration and precisely locating the substrate and mask over the application stations.

Referring to Fig. 6, the magnet **24** may be an extended stationary magnet. The stationary magnet may be provided with a low friction surface, such as Teflon™ so that the substrate may easily slide past the magnet surface. The magnet **24** extends between the containers **42** and **42'** and includes separately activated portions **25** and **25'** for attaching releasing the masks **12** from the substrate **10**.

Referring back to Fig. 1, as the substrate **10** and mask **12** are transported in registration through the application station **8**, the stationary source **14** applies material to the substrate **10** through the mask **12** to form a pattern on the substrate **10**. A variety of materials and application methods may be used, for example, organic materials may be evaporated or sublimated onto the substrate, charged particles such as ions may be applied via a particle accelerator, chemicals may be deposited on the substrate as a vapor, or metals may be deposited by sputtering. Other materials such as polymeric materials may be applied by spraying, inkjet deposition, or offset printing. All of these techniques are known in the art and used to apply materials to substrates. Either or both the display substrate **10** and the patterned mask **12** may be flexible and made of, for example, plastic, flexible glass, thin metal or a composite of these materials. The masks **12** can be cleaned and recycled after use, or may be used once and discarded, or the mask materials may be recycled to form new masks.

Flat panel light sources include a plurality of layers of materials provided by a variety of process steps. As shown in Fig. 6, the present invention may be employed to apply a variety of materials in successive layers to a substrate through one or more masks. A series of application stations **8** may be employed to sequentially apply successive layers of material and/or treatments to a substrate. These layers may utilize the same masks at each station **8** as shown, or may utilize different masks at different application stations for a plurality of material and/or treatment applications. Each application station **8** applies a particular material to form or modify a series of layers built up in successive planes on the substrate **10**.

After materials are deposited, a final deposition of encapsulating material may be applied to seal the materials on the substrate from the environment. A cutter **60** may then separate individual flat panel light sources from the continuous substrate.

Alternatively, successive stations may apply different materials in a single plane on the substrate. This is useful, for example, in depositing different light emitting materials for providing red, green, and blue light within a single layer and to form multiple layers for charge injection, charge transport, and light emission. Alternatively, successive stations may co-deposit materials in a plane.

Referring to Fig. 7, according to a further alternative embodiment, material from a plurality of linear sources **14** may be provided in parallel across the width of a substrate **10**. This arrangement is particularly useful for very wide substrates. Any of the application techniques described above may be employed in this embodiment and multiple application stations may also be used in parallel or sequentially to apply a variety of materials to a substrate through a plurality of patterned masks.

Alternatively, as shown in Figs. 8 and 9, the mask **12** may be translated between sources **14** in a direction perpendicular to the direction of travel of the substrate, by a translation mechanism **48** that translates the mask when it is dropped by magnets **24**. The mask **12** is replaced on the support after it is translated in a direction perpendicular to the long direction of the substrate. Materials are thereby applied in an identical pattern to different locations across the substrate **10**. At a first source **14a**, materials are applied while the mask pattern (shown for illustration purposes as a single mask opening **32**) is located in a first position relative to the edge of the substrate **10**. At a second source **14b**, the mask has been shifted perpendicular to the direction of travel of the substrate **10** and materials are applied in the same pattern in second position offset from the first position. At a third source **14c** (see Fig. 9), the mask has been further shifted and the materials are applied in the same pattern offset from the second position. This is particularly useful, for example, in applying repeated pixel patterns using

different materials such as red, green, and blue light emitting materials in a strip pattern.

The linear source, materials, and evaporative techniques are all known in the art and described for example, in the VanSlyke reference cited above. The specification and construction of masks are also known in the art and may be made of, for example, plastic, glass, or metal such as Invar. Typically, masks of 50 microns are suitable and may be composed of conventional materials, such as Invar, with suitably small coefficients of thermal expansion.

The substrate **10** may be made of any suitable flexible material for flat panel displays that can be provided on a roll. Suitable substrate materials include flexible glass, plastic, and metal or laminates. The substrates may be modified as part of the manufacturing process, for example, with the application of vapor barriers.

Applied materials may include light emitting materials such as organic materials used in the manufacture of organic light emitting diode (OLEDs) displays or light sources. Other materials may include semiconductor materials, conductive materials such as metals, dielectrics, active species such as chemicals that interact with thin films of deposited materials, for example to provide means for removal of materials or to encapsulate or seal a layer.

The present invention may also be combined with other coating or deposition methods known in the art, for example curtain coating, to deposit or process other materials. In addition the invention may be used to selectively modify the substrate for adhesion, electrical properties, dopants and other desirable treatments. Existing methods for cutting, sealing, bonding, and packaging the substrate may also be employed.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

8	application station
10	substrate
12	mask
14, a, b, c	material source
22	clamps
23	body portion
24	magnet
25	magnet portion
25’	magnet portion
27	clips
29	transport mechanism
32	mask opening
42	supply container
42’	receiving container
43	delivery means
46	elevator
48	translation mechanism
60	cutter
80	supply roll
82, 84	powered roller